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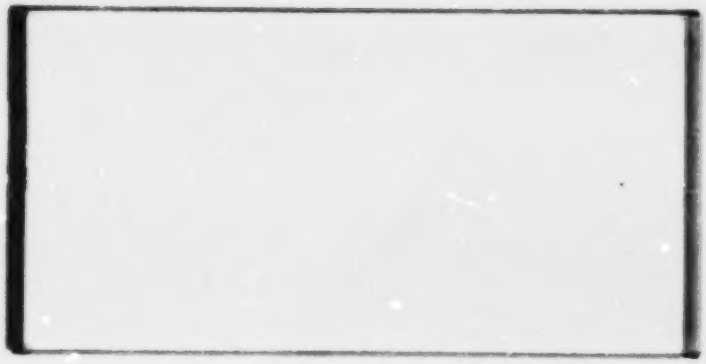

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INFLUENCE OF WATER CURRENT AND WAVE ACTION ON SUBSTRATE SELECTION BY LARVAL ROUND WHITEFISH

Report No. 84-111-K

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ABSTRACT

Larval round whitefish, Prosopium cylindraceum, showed a significant preference for a sand substrate while resting on the bottom. Water current alone or combined with wave action did not alter the species preference for a sand substrate. Substrate preference was not influenced by varying light levels during test conditions. The majority of larvae at any one time were swimming. Results suggested that field sampling for larval round whitefish should be conducted using a bottom sampling technique over areas of the lake where sand is the predominate substrate.

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To Dr. W.R. Effer
Manager,
Environmental Studies and
Assessments

Influence of Water Current and Wave Action
on Substrate Selection by Larval Round Whitefish

INTRODUCTION

At the request of the Environmental Studies and Assessments Department, a laboratory study was conducted to determine the influence of water current and wave action on substrate selection by larval round whitefish. This study was the second of two laboratory studies designed to observe the behaviour of larval round whitefish relative to environmental stimuli. The previous study indicated that the substrate preferred by larvae, regardless of size and onset of exogenous feeding or loss of yolk sac, was sand. In addition, the study noted that the majority of larvae during any of the observation periods were swimming rather than resting on the bottom of the experimental chambers (Ontario Hydro Research Division Report 83-57-K).

The goal of both studies was to gather information to aid in designing a whitefish larval fish sampling program. The capability to sample larval whitefish is required in order to comply with the Pickering B Discharge certificate of approval which requires assessment of the effects of the discharge on whitefish spawning success.

MATERIALS AND METHODS

Eggs were taken from adult round whitefish, captured in Lake Ontario at Thickson Point on Dec. 7,1982. Eggs were wet spawned and returned to the laboratory where they were maintained in darkness at a temperature of 6 degrees Celsius in a continuous flow of dechlorinated Toronto tap water (Lake Ontario). The egg incubation apparatus used was previously described in OHRD Report 76-499-K. Only larval fish with the yolk sack present (eleutheroembryonic phase of development) were used in the substrate preference tests.

Larval fish were placed in three rectangular experimental

chambers which measured 120X90X30 cm. Screen meshing (1.5mm) was used to cover the small end of each tank. Both chambers and screens were manufactured from polyvinyl chloride. The chambers were submerged in a 3.7 m diameter pool to the extent that 20 cm of water covered the substrates present in each chamber. Sand (0.3-0.5 mm), gravel (10-15 mm), and cobble (60-90 mm) substrates were used in the preference tests. Substrates were systematically arranged among chambers (Figure 1).

The pool which housed the experimental chambers was equipped to provide a range of current or no current conditions, as well as wave action. Two, 1 h.p. Myers "Ejecto" pumps provided an initial mean current velocity of 10.0±0.5 cm/s. Plastic dividers installed between chambers created a circular raceway with a nearly laminar water flow. Water current was measured using a Marsh/McBriney model 201 current meter. Waves were simulated using an air driven wave generator installed on the pool bottom. Air was pulsed through a pipe via a normally closed solenoid valve, which was connected to a solid state timer. This created waves with a wave length of 5.0 cm and amplitude of 5.0 cm.

The influence of water movement on substrate preference was tested under three conditions: current plus wave action, current alone, and static water. Behaviour of larvae (150 per tank) was observed on three separate occasions for each water condition. Mortality, number of larvae swimming, and number of larvae resting upon each substrate were monitored three times each day over three day periods. Daily observations were made when light conditions measured at these times were 1.0 lx , 8.0 lx , and <1.0 lx simulating early morning, noon, and night conditions. The number of larvae resting upon each substrate was expressed as a percent of the total on all substrates in the pool. Data were subjected to analysis of variance using the factors substrate, water condition and light level.

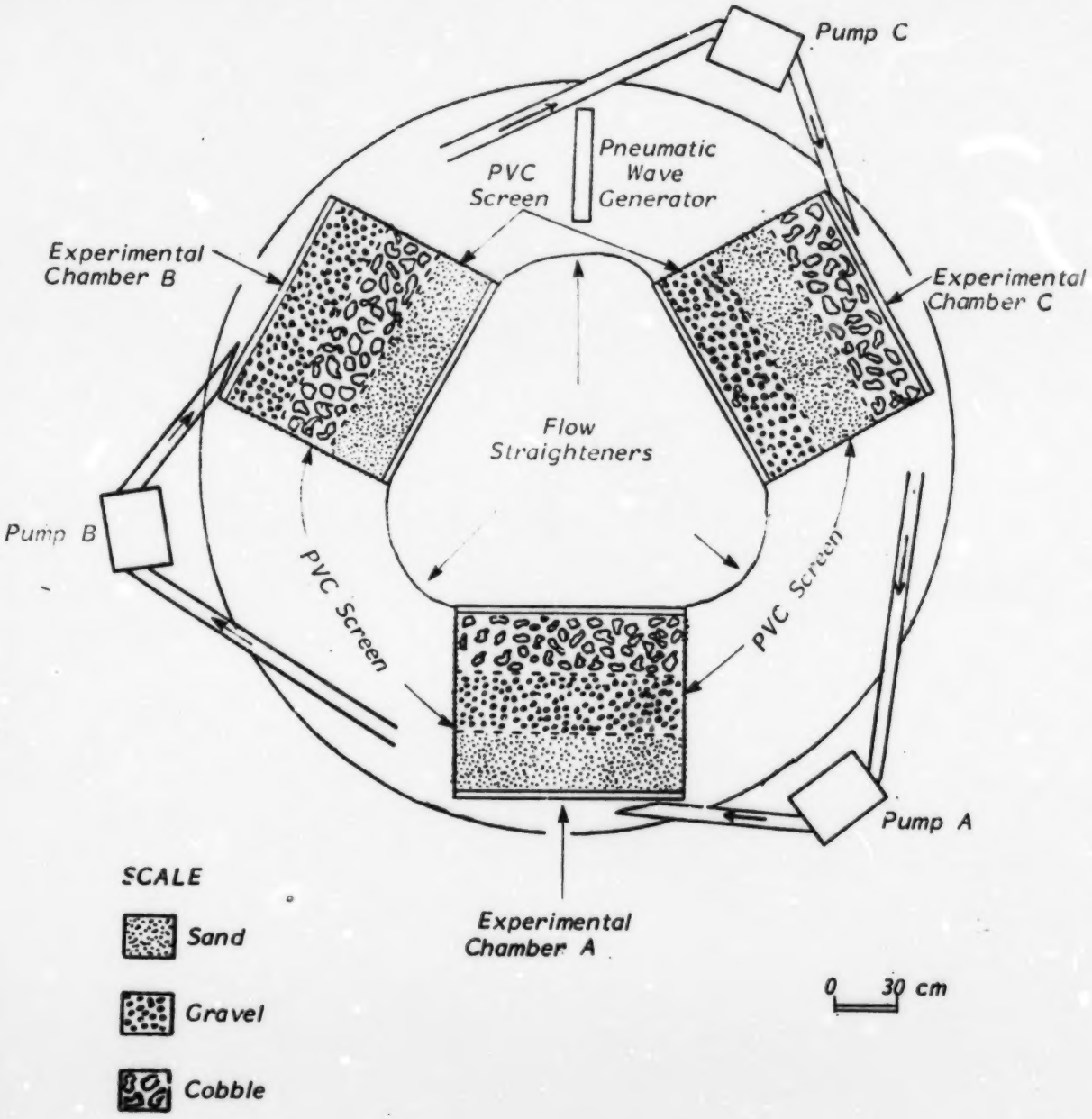

FIGURE 1

TOP VIEW OF THE 3.7 m DIAMETER CIRCULAR POOL CONTAINING THREE TEST CHAMBERS

RESULTS AND DISCUSSION

All larvae during the initial tests, with current velocity of 10 cm/s, were impinged on the screens covering the downstream end of the chambers. Subsequent reductions of the current to 8 and 6 cm/s also resulted in the total impingement of larvae. As a result it was concluded that the sustained swimming speed of the larvae would be used as the current velocity tested.

Sustained swimming speed of larval round whitefish was determined using larvae in the eleutheroembryonic stage (as used in the substrate preference experiments). A smaller version of the swimming speed tunnel described in Ontario Hydro Research Division Report 79-362-K was employed. The total volume of the tunnel was 22.8 liters. The acrylic test chamber measured 5.0 cm (I.D.) by 47 cm in length. Water velocities in a range of 0.5 to 10 cm/s were reproducible. Test procedures followed those described in Ontario Hydro Research Division Report 79-362-K with the following changes:

(a) five fish were used per replicate
(b) each velocity was maintained for 15 minutes
(c) velocities were increased stepwise in increments of 0.5 to 1.0 cm/s
(d) no acclimation period was used
(e) fish were only tested at the temperature to which they were exposed during the behavioural tests.

A plot of swimming speed and cumulative percent fatigued is shown in Figure 2. Sustained swimming speed was selected as the point of inflection, 3.6 ± 0.5 cm/s. The preference tests were subsequently conducted at their defined sustained swimming speed.

Larval mortality following the three day experimental period was lowest (<14%) under static conditions. Mortality for current alone and current plus wave action averaged 37% and 23% respectively (this excludes the abnormally high mortality observed in Tank C on March 2-4). The higher mortality during current and current/wave action conditions was due to impingement of larvae on the screens covering each end of the chambers.

The majority of larvae during any of the observational periods were swimming within 10 cm. of the substrates. Substrate was the only factor which significantly influenced the distribution of larvae observed on the bottom. The influence of light or water motion on their distribution was not significant (Table 1a). Of the total number of larvae observed on the bottom, 64 to 71% were found on the sand substrate (Figure 3), while those resting on gravel and cobble ranged from 13 to 22% with no apparent preference for either (Table 1b).

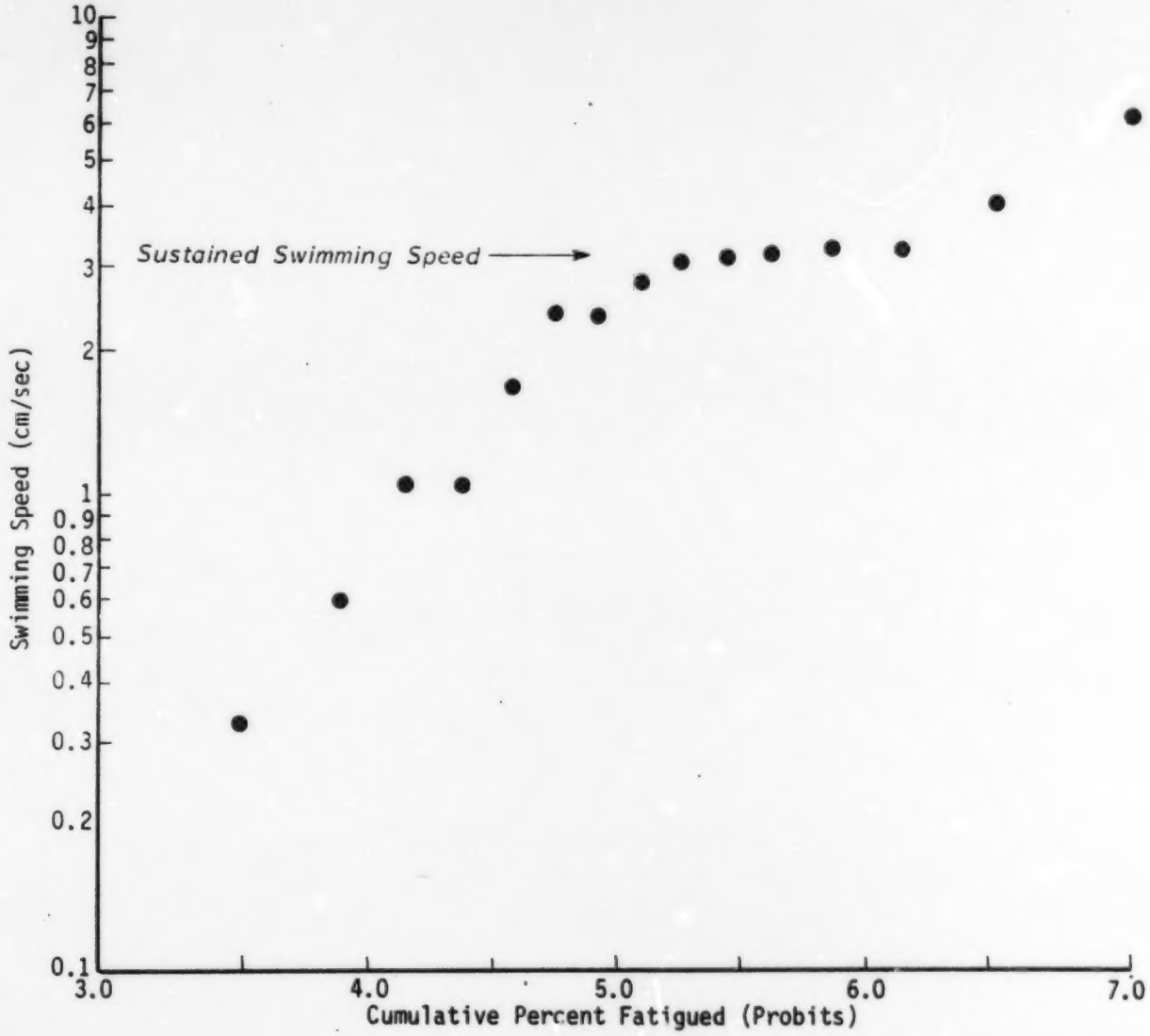

FIGURE 2

DISTRIBUTION OF FATIGUE SPEEDS FOR LARVAL ROUND WHITEFISH AT 6°C

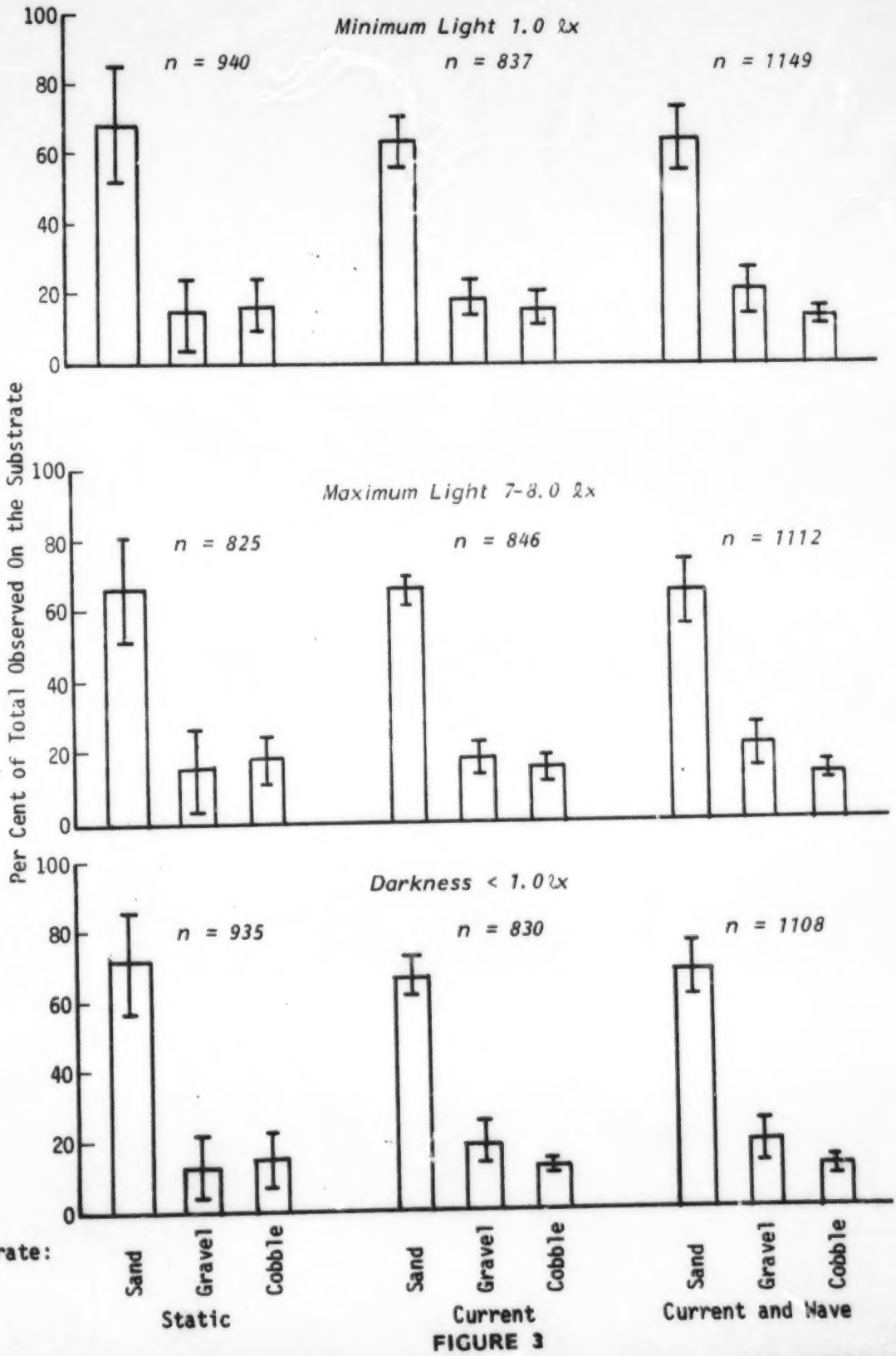

FIGURE 3

SUBSTRATE PREFERENCE OF LARVAL ROUND WHITEFISH UNDER THREE WATER CONDITIONS AND LIGHT REGIMES. VALUES ARE EXPRESSED AS AN AVERAGE PERCENT OF THE TOTAL NUMBER OBSERVED ON THE BOTTOM ± S.D.

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Table 1a

Three Way Analysis of Variance of Substrate Occupancy for the Factors Water Motion, Light Level, and Substrate Type

Source	degrees of freedom	Sums of Squares	Mean Square	F-RATIO
MOTION	2	0.00	0.00	0.00
LIGHT	2	0.00	0.00	0.00
SUBSTRATE	2	46007.14	23003.57	351.11
MOTXLIGHT	4	0.00	0.00	0.00
MOTXSUB	4	332.85	83.21	1.27
LIGHTXSUB	4	90.50	22.62	0.35
MOTXLIGHTXSUB	8	40.00	5.00	0.08
WITHIN	54	3537.92	65.52	
TOTAL	80	50008.41		

Table 1b

Multiple Range Test Comparing Substrate Occupancy Between Sand, Gravel and Cobble

Substrate type	COBBLE	GRAVEL	SAND
Mean percent occupancy	15%	18%	67%
Grouping of samples showing no statistical difference (x.05)			

These results were similar to a previous study which showed most larvae were swimming within 10 cm of the bottom during maximum light and dark conditions but chose to occupy sand while on the bottom (Ontario Hydro Research Division Report 83-57-k). Sand may be effective for camouflage since larvae contrasted less with sand than with the other two substrates. Other laboratory studies using brown and rainbow trout and juvenile smallmouth bass have also noted that fish chose a background which favoured protection against detection when exposed to environmental stimuli such as water current and illumination (Ritter and MacCrimmon 1973, and MacCrimmon and Robbins 1981).

It is interesting to note, however, that although preference for sand was not altered with the introduction of a 3.6 cm/s current, their distribution on sand did vary depending on the presence/absence of a current. In the absence of a current larvae

were more or less randomly distributed over the sand substrate. Subjected to a current larvae restricted themselves to shallow depressions in the sand.

This study indicates that a larval round whitefish field sampling program should employ a bottom sampling technique with effort concentrated over areas of sand. Sampling effort could be conducted during the day or evening since illumination appears to have little influence on their distribution. Water currents greater than 3.6 cm/s would influence their distribution.

In the vicinity of Pickering NGS bottom water movement was predominantly offshore with currents ranging from 3 - 11 cm/s (OHRD Report 83-531-K). Since these currents generally exceed the sustained swimming speed of larval round whitefish, newly hatched larvae may be redistributed offshore.

SUMMARY AND CONCLUSIONS

1) Larval round whitefish in an eleutheroembryonic stage of development showed a significant preference for sand substrate while resting on the bottom. This preference was not altered by various combinations of light intensity, water current, or wave action.

2) Laboratory studies of substrate preference indicate that field sampling programs for larval whitefish should employ a bottom sampling technique with effort concentrated over sand substrate.

Approved:

D. Harrison
Manager
Chemical Research Department

Submitted:

R.S. McKinley
Unit Head
Biological Research Section

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APPENDIX 1
LARVAL ROUND WHITEFISH-SUBSTRATE PREFERENCE

TREATMENT STATIC
CHAMBER A, REPLICATE 1

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/02/15	MIN	8.2	24	2	0	124	0	150
83/02/15	MAX	8.2	12	3	1	134	0	150
83/02/15	DARK	8.2	26	4	2	118	0	150
83/02/16	MIN	8.2	31	1	0	118	0	150
83/02/16	MAX	8.2	22	0	3	125	0	150
83/02/16	DARK	8.2	42	1	3	104	0	150
83/02/17	MIN	8.2	32	1	7	110	0	150
83/02/17	MAX	8.2	22	0	3	125	0	150
83/02/17	DARK	8.2	50	0	0	100	0	150

CHAMBER B, REPLICATE 1

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/02/15	MIN	8.2	28	2	0	120	0	150
83/02/15	MAX	8.2	19	0	6	125	0	150
83/02/15	DARK	8.2	22	2	8	118	0	150
83/02/16	MIN	8.2	24	1	6	117	2	150
83/02/16	MAX	8.2	24	1	3	120	0	148
83/02/16	DARK	8.2	14	1	1	132	0	148
83/02/17	MIN	8.2	40	0	0	147	1	148
83/02/17	MAX	8.2	33	0	2	112	0	147
83/02/17	DARK	8.2	31	2	0	114	0	147

CHAMBER C, REPLICATE 1

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/02/15	MIN	8.2	26	0	8	116	0	150
83/02/15	MAX	8.2	16	2	2	130	0	150
83/02/15	DARK	8.2	20	2	4	124	0	150
83/02/16	MIN	8.2	22	1	2	125	0	150
83/02/16	MAX	8.2	33	0	9	108	0	150
83/02/16	DARK	8.2	31	0	3	116	0	150
83/02/17	MIN	8.2	26	0	3	120	1	150
83/02/17	MAX	8.2	17	1	1	130	0	149
83/02/17	DARK	8.2	31	1	4	113	0	149

CHAMBER A, REPLICATE 2

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/03/06	MIN	6.8	34	9	5	97	5	150
83/03/06	MAX	6.8	36	4	5	100	0	145
83/03/06	DARK	6.8	36	3	6	100	0	145
83/03/08	MIN	6.3	37	6	10	91	1	145
83/03/08	MAX	6.3	37	6	10	91	0	144
83/03/08	DARK	6.3	38	6	9	91	0	144
83/03/09	MIN	6.8	30	5	15	92	2	144
83/03/09	MAX	6.8	36	5	15	86	0	142
83/03/09	DARK	6.8	45	3	14	80	0	142

CHAMBER B, REPLICATE 2

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/03/06	MIN	6.8	25	13	16	82	14	150
83/03/06	MAX	6.8	15	12	17	92	0	136
83/03/06	DARK	6.8	25	12	15	84	0	136
83/03/08	MIN	6.3	25	9	17	82	3	136
83/03/08	MAX	6.3	26	8	16	83	0	133
83/03/08	DARK	6.3	28	6	14	85	0	133
83/03/09	MIN	6.8	26	9	16	78	4	133
83/03/09	MAX	6.8	27	9	14	79	0	129
83/03/09	DARK	6.8	26	12	15	76	0	129

CHAMBER C, REPLICATE 2

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/03/06	MIN	6.8	3	10	1	133	3	150
83/03/06	MAX	6.8	3	8	1	135	0	147
83/03/06	DARK	6.8	6	8	2	131	0	147
83/03/08	MIN	6.3	9	1	1	135	1	147
83/03/08	MAX	6.3	10	1	1	134	0	146
83/03/08	DARK	6.3	11	2	1	132	0	146
83/03/09	MIN	6.8	9	1	2	134	0	146
83/03/09	MAX	6.8	9	1	1	135	0	146
83/03/09	DARK	6.8	9	1	1	135	0	146

CHAMBER A, REPLICATE 3

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/03/21	MIN	8.8	23	2	7	113	5	150
83/03/21	MAX	8.8	24	2	6	113	0	145
83/03/21	DARK	8.8	24	2	6	113	0	145
83/03/22	MIN	8.0	17	2	7	119	0	145
83/03/22	MAX	8.0	17	1	6	121	0	145
83/03/22	DARK	8.0	18	2	5	120	0	145
83/03/23	MIN	8.6	28	8	7	102	0	145
83/03/23	MAX	8.6	26	7	6	106	0	145
83/03/23	DARK	8.6	28	7	5	105	0	145

CHAMBER B, REPLICATE 3

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/03/21	MIN	8.8	26	5	11	107	1	150
83/03/21	MAX	8.8	27	3	10	109	0	149
83/03/21	DARK	8.8	26	3	8	112	0	149
83/03/22	MIN	8.0	28	14	7	100	0	149
83/03/22	MAX	8.0	27	13	8	101	0	149
83/03/22	DARK	8.0	27	13	8	101	0	149
83/03/23	MIN	8.6	27	2	5	115	0	149
83/03/23	MAX	8.6	28	1	4	116	0	149
83/03/23	DARK	8.6	27	1	5	116	0	149

CHAMBER C, REPLICATE 3

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/03/21	MIN	8.8	10	14	2	118	6	150
83/03/21	MAX	8.8	11	14	2	117	0	144
83/03/21	DARK	8.8	10	14	1	119	0	144
83/03/22	MIN	8.0	7	14	5	113	5	144
83/03/22	MAX	8.0	7	13	4	115	0	139
83/03/22	DARK	8.0	7	13	4	115	0	139
83/03/23	MIN	8.6	12	12	3	112	0	139
83/03/23	MAX	8.6	12	11	2	114	0	139
83/03/23	DARK	8.6	12	10	3	114	0	139

TREATMENT CURRENT ALONE

CHAMBER A, REPLICATE 1

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/02/22	MIN	7.0	11	3	5	119	12	150
83/02/22	MAX	7.0	10	2	1	125	0	138
83/02/22	DARK	7.0	8	4	1	125	0	138
83/02/23	MIN	7.3	2	1	3	105	27	138
83/02/23	MAX	7.3	3	6	1	101	0	111
83/02/23	DARK	7.3	4	6	1	100	0	111
83/02/24	MIN	7.3	3	2	0	103	3	111
83/02/24	MAX	7.3	4	2	0	103	0	109
83/02/24	DARK	7.3	4	2	0	103	0	109

CHAMBER B, REPLICATE 1

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/02/22	MIN	7.0	14	2	14	101	16	147
83/02/22	MAX	7.0	19	0	7	105	0	131
83/02/22	DARK	7.0	18	0	4	109	0	131
83/02/23	MIN	7.3	6	0	3	122	0	131
83/02/23	MAX	7.3	9	0	9	78	5	101
83/02/23	DARK	7.3	4	0	2	89	1	96
83/02/24	MIN	7.3	4	1	7	83	0	95
83/02/24	MAX	7.3	5	1	5	84	0	95
83/02/24	DARK	7.3	5	1	6	83	0	95

CHAMBER C, REPLICATE 1

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/02/22	MIN	7.0	37	5	5	92	10	149
83/02/22	MAX	7.0	35	5	5	93	1	139
83/02/22	DARK	7.0	30	1	5	101	1	138
83/02/23	MIN	7.3	23	4	3	106	1	137
83/02/23	MAX	7.3	25	8	2	101	1	137
83/02/23	DARK	7.3	21	13	5	96	0	135
83/02/24	MIN	7.3	24	5	3	97	6	135
83/02/24	MAX	7.3	22	5	3	97	2	129
83/02/24	DARK	7.3	23	5	3	94	2	127

CHAMBER A, REPLICATE 2

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/03/10	MIN	7.4	45	7	9	85	3	149
83/03/10	MAX	7.4	43	7	9	87	0	146
83/03/10	DARK	7.4	46	7	8	85	0	146
83/03/11	MIN	6.8	30	2	1	107	6	146
83/03/11	MAX	6.8	30	2	1	107	0	140
83/03/11	DARK	6.8	33	3	5	99	0	140
83/03/14	MIN	6.4	34	5	6	95	0	140
83/03/14	MAX	6.4	43	6	6	85	0	140
83/03/14	DARK	6.4	41	6	5	88	0	140

CHAMBER B, REPLICATE 2

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/03/10	MIN	7.4	26	7	8	83	5	129
83/03/10	MAX	7.4	26	6	8	84	0	124
83/03/10	DARK	7.4	28	6	7	83	0	124
83/03/11	MIN	6.8	26	5	11	81	1	124
83/03/11	MAX	6.8	27	6	10	80	0	123
83/03/11	DARK	6.8	25	7	7	84	0	123
83/03/14	MIN	6.4	23	7	22	71	0	123
83/03/14	MAX	6.4	25	4	15	79	0	123
83/03/14	DARK	6.4	22	4	13	84	0	123

CHAMBER C, REPLICATE 2

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/03/10	MIN	7.4	17	8	2	114	5	146
83/03/10	MAX	7.4	24	7	1	109	0	141
83/03/10	DARK	7.4	24	16	2	99	0	141
83/03/11	MIN	6.8	18	25	0	94	4	141
83/03/11	MAX	6.8	19	22	3	93	0	137
83/03/11	DARK	6.8	17	35	5	80	0	137
83/03/14	MIN	6.4	13	21	2	98	3	137
83/03/14	MAX	6.4	17	21	3	93	0	134
83/03/14	DARK	6.4	16	22	2	94	0	134

CHAMBER A, REPLICATE 3

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/03/24	MIN	8.6	22	1	4	118	0	145
83/03/24	MAX	8.6	24	2	4	115	0	145
83/03/24	DARK	8.6	25	2	5	113	0	145
83/03/25	MIN	8.6	23	0	3	119	0	145
83/03/25	MAX	8.6	24	0	4	117	0	145
83/03/25	DARK	8.6	23	1	3	118	0	145
83/03/28	MIN	8.7	22	3	3	116	1	145
83/03/28	MAX	8.7	22	3	3	116	0	144
83/03/28	DARK	8.7	23	2	1	118	0	144

CHAMBER B, REPLICATE 3

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/03/24	MIN	8.6	27	7	5	110	0	149
83/03/24	MAX	8.6	25	6	6	112	0	149
83/03/24	DARK	8.6	27	6	5	111	0	149
83/03/25	MIN	8.6	27	6	4	112	0	149
83/03/25	MAX	8.6	26	6	3	114	0	149
83/03/25	DARK	8.6	28	4	3	114	0	149
83/03/28	MIN	8.7	26	5	10	108	0	149
83/03/28	MAX	8.7	24	5	10	110	0	149
83/03/28	DARK	8.7	23	4	9	113	0	149

CHAMBER C, REPLICATE 3

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/03/24	MIN	8.6	8	8	0	123	0	139
83/03/24	MAX	8.6	8	8	0	123	0	139
83/03/24	DARK	8.6	8	6	1	124	0	139
83/03/25	MIN	8.6	10	6	0	123	0	139
83/03/25	MAX	8.6	8	6	1	124	0	139
83/03/25	DARK	8.6	8	6	1	124	0	139
83/03/28	MIN	8.7	12	5	0	122	0	139
83/03/28	MAX	8.7	12	5	0	122	0	139
83/03/28	DARK	8.7	12	5	1	121	0	139

TREATMENT CURRENT PLUS WAVE ACTION

CHAMBER A, REPLICATE 1

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/03/02	MIN	6.5	63	10	8	69	0	150
83/03/02	MAX	6.5	62	11	4	73	0	150
83/03/02	DARK	6.5	59	8	4	79	0	150
83/03/03	MIN	6.2	46	12	6	59	27	150
83/03/03	MAX	6.2	51	9	5	58	0	123
83/03/03	DARK	6.2	53	10	6	54	0	123
83/03/04	MIN	6.5	57	7	2	50	7	123
83/03/04	MAX	6.5	53	7	3	53	0	116
83/03/04	DARK	6.5	53	7	2	54	C	116

CHAMBER B, REPLICATE 1

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/03/02	MIN	6.5	42	10	27	69	2	150
83/03/02	MAX	6.5	46	16	25	59	2	148
83/03/02	DARK	6.5	43	6	18	79	0	146
83/03/03	MIN	6.2	39	10	16	81	0	146
83/03/03	MAX	6.2	41	9	16	80	0	146
83/03/03	DARK	6.2	44	9	17	76	0	146
83/03/04	MIN	6.5	32	14	11	83	6	146
83/03/04	MAX	6.5	32	14	11	83	0	140
83/03/04	DARK	6.5	34	12	11	83	0	140

CHAMBER C, REPLICATE 1

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/03/02	MIN	6.5	17	2	1	69	61	150
83/03/02	MAX	6.5	25	1	0	59	4	89
83/03/02	DARK	6.5	20	1	1	63	0	85
83/03/03	MIN	6.2	14	0	2	45	24	85
83/03/03	MAX	6.2	18	0	2	24	17	61
83/03/03	DARK	6.2	17	0	3	22	2	44
83/03/04	MIN	6.5	13	0	0	21	8	42
83/03/04	MAX	6.5	13	0	0	21	0	34
83/03/04	DARK	6.5	14	0	1	19	0	34

CHAMBER A, REPLICATE 2

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/03/16	MIN	7.1	37	7	3	93	0	140
83/03/16	MAX	7.1	36	7	3	94	0	140
83/03/16	DARK	7.1	36	7	3	94	0	140
83/03/17	MIN	7.9	32	6	3	99	0	140
83/03/17	MAX	7.9	33	5	3	99	0	140
83/03/17	DARK	7.9	41	5	3	91	0	140
83/03/18	MIN	7.4	31	3	11	92	3	140
83/03/18	MAX	7.4	33	4	11	89	0	137
83/03/18	DARK	7.4	34	4	7	92	0	137

CHAMBER B, REPLICATE 2

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/03/16	MIN	7.1	25	8	9	81	0	123
83/03/16	MAX	7.1	26	8	7	82	0	123
83/03/16	DARK	7.1	27	6	16	74	0	123
83/03/17	MIN	7.9	27	6	17	73	0	123
83/03/17	MAX	7.9	26	5	16	76	0	123
83/03/17	DARK	7.9	27	6	17	73	0	123
83/03/18	MIN	7.4	27	8	17	66	5	123
83/03/18	MAX	7.4	28	8	6	76	0	118
83/03/18	DARK	7.4	29	6	6	77	0	118

CHAMBER C, REPLICATE 2

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/03/16	MIN	7.1	10	23	1	100	0	134
83/03/16	MAX	7.1	7	22	0	105	0	134
83/03/16	DARK	7.1	7	20	0	107	0	134
83/03/17	MIN	7.9	12	29	1	92	0	134
83/03/17	MAX	7.9	10	27	1	96	0	134
83/03/17	DARK	7.9	10	26	1	97	0	134
83/03/18	MIN	7.4	8	19	1	102	4	134
83/03/18	MAX	7.4	9	21	1	99	0	130
83/03/18	DARK	7.4	8	20	0	102	0	130

CHAMBER A, REPLICATE 3

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/03/29	MIN	9.4	21	3	4	116	0	144
83/03/29	MAX	9.4	22	4	5	113	0	144
83/03/29	DARK	9.4	23	5	5	111	0	144
83/03/30	MIN	10.0	29	3	6	105	1	144
83/03/30	MAX	10.0	28	2	3	110	0	143
83/03/30	DARK	10.0	29	2	3	109	0	143
83/03/31	MIN	10.0	28	2	2	111	0	143
83/03/31	MAX	10.0	27	3	2	111	0	143
83/03/31	DARK	10.0	29	3	0	111	0	143

CHAMBER B, REPLICATE 3

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/03/29	MIN	9.4	24	4	8	113	0	149
83/03/29	MAX	9.4	24	4	6	115	0	149
83/03/29	DARK	9.4	27	5	5	112	0	149
83/03/30	MIN	10.0	36	4	7	102	0	149
83/03/30	MAX	10.0	36	6	5	102	0	149
83/03/30	DARK	10.0	33	5	6	105	0	149
83/03/31	MIN	10.0	33	2	4	110	0	149
83/03/31	MAX	10.0	30	3	3	113	0	149
83/03/31	DARK	10.0	31	4	4	110	0	149

CHAMBER C, REPLICATE 3

DATE	LIGHT	TEMP °C	NUMBER OF FISH IN CONTACT WITH EACH SUBSTRATE SAND	GRAVEL	COBBLE	SWIMMING	MORTALITY	TOTAL
83/03/29	MIN	9.4	12	5	0	122	0	139
83/03/29	MAX	9.4	10	5	1	123	0	139
83/03/29	DARK	9.4	11	4	1	123	0	139
83/03/30	MIN	10.0	10	13	0	114	2	139
83/03/30	MAX	10.0	8	8	0	121	0	137
83/03/30	DARK	10.0	8	8	0	121	0	137
83/03/31	MIN	10.0	8	7	0	122	0	137
83/03/31	MAX	10.0	9	8	1	119	0	137
83/03/31	DARK	10.0	8	7	0	122	0	137

POOR

QUALITY

ORIGINAL